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Rapid Emergency Medicine Score (REMS) in the Trauma Population: A Retrospective Study

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ABSTRACT

Introduction: Injury scoring systems are utilised to assess injury severity and provide an objective measurement for treatment and appropriate allocation of health care resources. The Rapid Emergency Medicine Score (REMS) is an attenuated version of the Acute Physiology and Chronic Health Evaluation (APACHE) II score and has utility in non-surgical patients, but has yet to be tested among the trauma population. The objective of this study was to evaluate the predictive ability of REMS as a risk stratification tool to predict in-hospital mortality in traumatically-injured patients. Secondary objectives included comparing REMS to the Revised Trauma Score (RTS), the Injury Severity Score (ISS), and the Shock Index (SI) to determine which scoring scale is most accurate in predicting mortality.

Methods: A retrospective chart review of the trauma registry at an urban academic American College of Surgeons (ACS) Level 1 trauma center was performed. The study analyzed 3,680 patients admitted over a four-year period. REMS was calculated from data available on arrival to the Emergency Department (age, blood pressure, heart rate, Glasgow Coma Scale, respiratory rate, peripheral oxygen saturation) then compared to mortality. The discriminate power of REMS, RTS, ISS, and SI were compared using the area under the receiver operator characteristic curve (AUC).

Results: A higher REMS was associated with increased mortality ($p < 0.0001$). An increase of 1 point in the 26-point REMS scale was associated with an odds ratio of 1.51 for in-hospital death (95% CI 1.45 - 1.58). REMS (AUC 0.91 ± 0.02) was found to be superior to RTS (AUC 0.89 ± 0.04), ISS (AUC 0.87 ± 0.01), and SI (AUC 0.55 ± 0.31) in predicting in-hospital mortality.

Conclusions: In the trauma population, REMS appears to be a simple and accurate predictor of in-hospital mortality. Moreover, REMS performed better than traditionally-used trauma scoring systems, including RTS, ISS and SI.

Strengths & Limitations

- This is the first study to demonstrate the applicability of REMS, a more rapid and less invasive version of the APACHE II score, to traumatically-injured patients.
- REMS, which is calculated from readily-available parameters, performs favorably in comparison to existing trauma scores to predict in-hospital mortality.
- While the study analyzed a large sample size at a single urban academic trauma center, attempts to extrapolate results to other trauma populations may not be reliable.
- REMS was originally derived from the medicine population, therefore the scoring system does not differentiate between injury types, which are known factors in predicting mortality.

Introduction

Trauma and unintentional injury is the leading cause of death for all individuals less than 44 years of age which results in a major cost burden for the health care system.[1] Current literature supports that early diagnosis and appropriate treatment both improve outcomes and are cost effective. Over the past decade, scoring systems have been utilised to assess injury severity and provide an objective measure for treatment and appropriate allocation of health care resources. The Acute Physiology and Chronic Health Evaluation (APACHE II) is a validated scale that assesses severity of illness among, non-surgical, surgical, and intensive care patients.[2] Calculation of an APACHE II score requires blood chemistry analysis, which renders this score impractical for the rapid injury severity scoring necessary in the emergency department (ED) or in the field. The Rapid Emergency Medicine Score (REMS), an attenuated version of APACHE II, allows for prompt calculation.[2, 3] REMS is a composite score consisting of the Glasgow Coma Scale (GCS), respiratory rate (RR), oxygen saturation, blood pressure, heart rate (HR) and age.[4] Among non-surgical patients who present to the ED, REMS has proven to be a valid predictor of mortality.

While many ED scoring methodologies focus on evaluating short-term outcomes, REMS has been shown to predict mortality at one week (HR 1.34, 95% CI 1.30-1.37), one month (HR 1.30, 95% CI 1.27-1.32) and three months (HR 1.26, 95% CI 1.24-1.28).[2] An additional study comparing area under the receiver operating curve (AUC) for the Rapid Acute Physiology Score (0.64, 95% CI 0.59-0.69) and REMS (0.74, 95% CI 0.70-0.78) in non-surgical ED patients determined superiority of the REMS.[4, 5] Every point increase in the 26-point REMS score was associated with an odds ratio (OR) of

1.40 (95% CI 1.36-1.45, $p < 0.0001$) for in-hospital mortality.[4] While there have been extensive publications reporting sound predicative validity for this score among non-surgical patients, the utility of REMS in the trauma population has yet to be analyzed.

The purpose of this study was to evaluate REMS as a risk stratification tool to predict in-hospital mortality in traumatically injured patients. Secondary objectives included comparing REMS to the Revised Trauma Score (RTS), the Injury Severity Score (ISS), and the Shock Index (SI) to determine which scoring system was a superior predictor of mortality, in addition to examining the six parameters of REMS to determine which, if any, were most predictive of mortality.

Materials and Methods

Study Design: This was a retrospective chart review of the trauma registry at an urban academic American College of Surgeons (ACS) Level 1 trauma center. The study was reviewed by the hospital institutional review board, The University of Kansas Medical Center Human Subjects Committee, and a waiver of informed consent was granted.

Study Population: Analysis focused on 3,680 trauma patients aged 14 years and older admitted to the hospital over a four-year period. Patients transferred from other hospitals were excluded from the study; for these patients, vital signs may have changed from initial values due to treatment at institution, affecting REMS calculations. Patients who suffered from burn or drowning-related injuries were also excluded from the study. Finally, 158 patients with vital sign documentation that was insufficient for REMS calculation were also excluded. 47 patients were missing non-REMS injury scores (i.e. SI, ISS, RTS); these patients were included in all the REMS analyses except calculation of the AUC for their respective scoring systems.

Protocol: Variables collected included age, date and time of arrival, race, sex, systolic blood pressure (SBP), diastolic blood pressure (DBP), RR, HR, oxygen saturation, length of stay, and GCS. The ISS and RTS scores were calculated by and obtained from the trauma registry. The mean arterial pressure (MAP) and SI (HR divided by SBP) were calculated during data analysis.

Measurements: The APACHE II score is utilised to classify disease severity in the hospital setting, incorporating body temperature, RR, HR, MAP (calculated with SBP and DBP), oxygenation of arterial blood, arterial pH, serum sodium and potassium levels, serum creatinine, hematocrit, white blood cell count, and GCS.[6] REMS preserves the more readily-obtained vital signs (RR, HR, MAP, GCS) while also considering age and oxygen saturation.[4] In REMS calculation, age is assigned a value from 0 to 6, and the remaining five variables are each assigned a score from 0 to 4 (Table 1). REMS is a sum of these values with a maximum composite score of 26, with higher values being indicative of worse prognosis.

In this study, REMS was compared to three currently utilised injury scoring systems, including SI, ISS and RTS, to determine which measure was superior in predicting mortality. SI is calculated by dividing heart rate by systolic blood pressure and has proven useful in predicting mortality and the severity of illness in traumatically ill patients.[7, 8] Likewise, the ISS correlates with mortality. In contrast, the ISS is an anatomically-based scoring system based on injuries to major body regions including the head and neck, face, chest, abdomen and pelvic contents, extremities and pelvic girdle and external.[9, 10] The ISS is useful for assessment following motor vehicle collisions. The ISS algorithm incorporates points from each region with a maximum score of 75 (higher values represent more serious trauma). Finally, the RTS can be used by pre-hospital emergency personnel to assist with triage of injured patients. The variables include RR, SBP, and GCS,[11], and the un-weighted RTS is calculated by adding the values assigned for each parameter against a maximum possible score of 12.

Data Analysis: Continuous variables were described using mean and standard deviation. Similarly, categorical variables were described using frequency and percentage. Parametric tests were used for the comparisons between groups: Chi-square test in the case of categorical variables and the t-test in the case of continuous variables. Correlations were tested using Spearman test. Sensitivity and specificity were plotted using the receiver operating characteristic (ROC) curve. The discriminate power of REMS, RTS, ISS, and SI was compared using the AUC. Statistically significant associations and differences were identified by *p*-values of less than 0.05. All analyses were conducted using SAS version 9.3 (copyright© 2002–2008 by SAS Institute Inc., Cary, NC, USA).

Results

Of the patients studied, 3,489 (94.8%) lived and 191 (5.2%) died. Characteristics of the study sample are included in Table 2. Patients who lived had a mean age of 36.5 ± 17.0 years, 73.7% were male, 62.5% were Caucasian, the average REMS was 3.4 (± 3.2) and the average length of stay was 7.6 (± 15.4) days. Patients who died had a mean age of 43.7 years, 77.0% were male, 59.2% were Caucasian, the average REMS was 11.8, and the average length of stay was 4.4 days.

A higher REMS was associated with increased mortality ($p < 0.0001$, Table 3). Patients with REMS less than 6, from 6 to 9 and greater than 9 had mortalities of 0.9%, 6.7% and 39.3%, respectively. An increase of one point within the 26-point REMS was associated with an OR of 1.51 for in-hospital death (95% CI 1.45 to 1.58).

Patients with low REMS scores who died presented to the ED with lower median GCS than those who survived. The median GCS for patients with REMS of 3 to 5 and 6 to 9 who died was 1.5 ($p < 0.0001$) and 8 ($p < 0.0001$) points lower than those who lived. Patients with high REMS scores who lived presented to the ED with a higher median age than those who died. The median age for patients with REMS of 16 to 19 and 20 to 21 who lived was 45.5 ($p = 0.01$) and 50 ($p = 0.13$) years older than those who died.

Secondarily, REMS was compared to three additional injury severity scoring systems (Table 4). REMS (AUC 0.91 ± 0.02) was found to be superior to RTS (AUC 0.89 ± 0.04), ISS (AUC 0.87 ± 0.01), and SI (AUC 0.55 ± 0.31) in predicting in-hospital mortality (Figure 1). The mean SI for patients that lived was 0.69 (± 0.22) and 0.79 (± 0.40) for those who died. The mean RTS for patients that lived was 7.4 (± 1.3) and 3.5 (± 2.7) for those who died. Lastly, the mean ISS score for patients that lived was 11.3 (± 10.0) and 30.0 (± 14.6) for those who died.

While multivariable logistic regression indicated that HR and RR individually did not predict mortality, the other four REMS parameters did (Table 5). GCS was the strongest predictor of mortality (OR 0.743, 95% CI 0.71 to 0.78). While not directly assessed by REMS, injury type also impacts patient mortality rates (Table 6). Patients with penetrating trauma experienced higher mortality rates than those with blunt force trauma (8.0% versus 4.4%, $p < 0.0001$).

Discussion

Despite recent improvements in trauma systems and their resulting decrease in preventable deaths, trauma continues to be the leading cause of mortality for those under the age of 44 years in the United States.[12] Trauma systems rely on imperfect and subjective tools to triage critically injured patients to the appropriate center. Currently, emergency medical service (EMS) and trauma care providers utilise a variety of factors such as blood pressure, RR, GCS, as well as mechanism of injury to prioritised responses and resources. With increasing rates of ED and trauma diversion, particularly in urban settings, efficient allocation of resources is more crucial than ever.[13] Organised and inclusive trauma systems depend on patients being routed to the closest and most appropriate center capable of caring for the patient. Any tool that can match true severity with the highest possible resource within the system may ensure that higher level centers are able to concentrate on patients most in need of their capabilities.[22-25] In particular, REMS appears to provide an effective balance between the predictive ability and the practical application which are necessary for the trauma setting. Unlike systems used elsewhere in the hospital, REMS does not require invasive or time-consuming lab values such as lactate, base deficit, mixed venous oxygen saturation, and cutaneous tissue oxygen saturation.[14-19] Rather, REMS utilises readily available parameters available both in the pre-hospital environment and in the ED.

The current body of literature related to REMS examines its application among non-surgical medicine patients. Studies conducted by Olsson et al., have concluded that use of the REMS among non-surgical patients in the ED is powerful in predicting both in-hospital and long-term mortality. In their studies, their research showed that all six REMS parameters were predictive of mortality. Similarly, Goodcare et al., found REMS to be effective in predicting mortality amongst medicine patients, although, age, GCS, and oxygen saturation were the only REMS parameters that strongly correlated with mortality. Our study indicates that applying REMS to the trauma population yields similar results and that REMS is a strong predictor of mortality.

It is important to note that REMS, like other trauma scoring methods, was originally devised using population-level data. Applying REMS at the individual patient level yields an estimated mortality percentage; because actual outcomes are binary (i.e. alive or dead), it would not be unexpected to for a very limited number of patients with low REMS to die and those with high REMS to live.

In this study, REMS outperformed all other measures in predicting mortality. ISS was nearly as predictive of mortality but is a retrospective system whose score can only be determined after diagnosis. ISS is therefore better suited as a benchmark for comparison (between patient groups or trauma centers) and not practically useful as a triage tool. While SI, which is calculated using two readily available vitals (HR and SBP), is both simple and fast to utilise, it severely underperformed REMS in predicting mortality. Un-weighted RTS was found to be the most effective alternative to REMS as a triage tool; its strength in predicting mortality was similar to that of REMS, but RTS uses only a subset of REMS measures (GCS, SBP and RR) and a 0 to 4 point scale for each variable. When compared to REMS, RTS affords a small amount of predictive ability in return for simplicity.

This study expands the usefulness of REMS in the ED, demonstrating its capability for predicting mortality in the trauma population. However, since REMS components and values were derived using data from a medicine population, further analysis of the applicability to a trauma population may be beneficial. Underlying reasons may include that medicine patients are more likely to have chronic comorbidities that may contribute to differing baseline vitals leading to a score variation. In addition, medicine patients may have a greater portion of their score attributable to age in comparison to that of the trauma population, which often consists of younger, otherwise healthy adults. Similar to Goodcare et al., this study found that the REMS components correlated with mortality were GCS, oxygen saturation, age, and MAP; of those, GCS was found to have the strongest predictor of mortality among the trauma population, while HR and RR did not exhibit any statistically significance.

Analysis suggests that GCS may be underweighted in the REMS calculation for trauma patients. At the lower end of the REMS scale (scores of 3 to 5 and 6 to 9), patients who died presented with a lower average GCS than those who lived. For REMS of 3 to 5, the average GCS for those who died was 11.1 (9 to 12 is classified as a moderate head injury[20]) compared to 14.2 (13 to 15 is classified as a mild head injury) for those who lived. For REMS of 6 to 9, the average GCS for those who died was 8.4 (≤ 8 is classified as a severe head injury) compared to 11.5 (moderate head injury) for those who lived. In a study of geriatric trauma, Champion et al., found a difference in mortality between trauma patients older than 65 (19.0%) and those younger than 65

(9.8%).[21] This difference in mortality may be due to the factor of age and the weight it carries within the REMS calculation methodology. However, our findings suggest that age may be over-weighted in the REMS calculation for trauma patients. At the higher end of the REMS scale (scores of 16 to 19 and 20 to 21), patients who survived presented with a greater average age; in these cases, a greater portion of the composite REMS score came from age.

REMS was derived from the medicine population; as a result, the scoring system does not differentiate between injury types. For the trauma population, however, injury type is a significant factor in mortality prediction. A significant difference in average mortality rates was demonstrated in patients presenting with blunt (4.4%) versus penetrating (8.0%) injury types. Differences in mortality rates by injury type persist at all levels of REMS.

This study, which analyzed a large number of trauma patients within a single hospital system, does possess several limitations. First, this was a retrospective analysis. As with any such study, potential disadvantages include the possibility of selection bias. Second, the study excluded 158 potential records from the analysis due to missing patient data required to calculate REMS. 47 patients were excluded from the calculation of the due to missing non-REMS injury scores (i.e. RTS, ISS, SI). Finally, because the study is based on data from a single urban academic ACS Level 1 trauma center, attempts to extrapolate results to other trauma populations may not be reliable. Given the focused population, opportunities exist for future expansion and improvement, such as conducting a prospective study on the predictive capability of REMS on mortality, and using a larger, more diverse trauma dataset. Evaluating REMS in the pre-hospital setting and monitoring the change in REMS from initial EMS contact to trauma center arrival may prove to be useful for EMS and for the ED by enhancing the effectiveness of the triage process, the appropriate routing of patients, and the utilization of trauma resources.

Conclusions

Though initially designed for the medicine population, REMS was found to be a strong predictor of in-hospital mortality for the trauma population. REMS outperformed traditionally used trauma scoring systems including RTS, ISS, and SI. This study also indicates potential opportunities to better apply REMS to the trauma population. REMS components HR and RR were found to have no statistically significant difference in mortality prediction, while age and GCS were either over- or under-weighted in the REMS calculation. Injury type is an important predictor of mortality in trauma patients, and it was not included in the REMS calculation. Each of these represents an opportunity for future study.

Key Messages

- REMS is a more rapid and less invasive form of APACHE II, utilizing age, blood pressure, HR, GCS, RR, and peripheral oxygen saturation
- REMS is a better predictor of mortality in the trauma population than RTS, ISS or SI
- Age, MAP, oxygen saturation and GCS correlate with mortality, with GCS exhibiting the strongest correlation

List of Abbreviations

APACHE: Acute Physiology and Chronic Health Evaluation

AUC: Area under Receiver Operator Characteristic (ROC) Curve

CI: Confidence Interval

ED: Emergency Department

EMS: Emergency Medical Service

GCS: Glasgow Coma Score

HR: Heart Rate

ISS: Injury Severity Score

OR: Odds Ratio

REMS: Rapid Emergency Medicine Score

ROC: Receiver Operator Characteristic

RTS: Revised Trauma Score

SI: Shock Index

Tables and Captions

Table 1 ***REMS Scoring System***

	Score						
Variable	0	+1	+2	+3	+4	+5	+6
Age (years)	<45		45-54	55-64		65-74	>74
MAP	70-109		110-129 50-69	130-159	>159 ≤ 49		
HR (beats/min)	70-109		110-139 55-69	140-179 40-54	>179 ≤39		
RR (breaths/min)	12-24	25-34 10-11	6-9	35-49	>49 ≤ 5		
O_2 Saturation (%)	>89	86-89		75-85	<75		
GCS	14 or 15	11-13	8-10	5-7	3 or 4		

MAP, Mean Arterial Pressure; HR, Heart Rate/Pulse; RR, Respiratory Rate; GCS, Glasgow Coma Score

Table 2 ***Baseline Characteristics and Hospital Course for 3,680 Trauma Patients***

	Dead (N=191) Mean (SD)*	**Alive (N=3,489) Mean (SD)***	***p*-Value**
Age, yrs	43.7 (21.0)	36.5 (17.0)	<0.0001
Male, (%)	77.0	73.7	0.0472
Race, (%)			0.0564
White	59.2	62.4	
Black	23.5	23.2	
Other	17.3	14.4	
Length of Stay	4.4 (8.0)	7.6 (15.2)	0. 0043

* Except where noted as %.

Table 3 ***REMS Score Characteristics*** (p < 0.0001) ***3,680 Trauma Patients***

REMS	**Alive (N)**	**Dead (N)**	**Mortality (%)**
0-2	1749	6	0.3%
3-5	999	20	2.0%
6-9	547	39	6.7%
10-11	110	28	20.3%
12-13	53	26	32.9%
14-15	22	18	45.0%
16-19	8	33	24.2%
20-21	1	13	92.9%
22-26	0	8	100.0%
Total	3489	191	5.2%

Table 4	*Injury Scores for 3,680 Trauma Patients*			
	N	**Dead Mean (SD)**	**Alive Mean (SD)**	***p*-Value**
REMS Score	3,680	11.8 (5.4)	3.4 (3.2)	<0.0001
SI	3,633	0.79 (0.40)	0.69 (0.22)	<0.0001
RTS	3,680	3.5 (2.7)	7.4 (1.3)	<0.0001
ISS	3,671	30.0 (14.6)	11.3 (10.0)	<0.0001

Table 5	*Multiple Logistic Regression for All Parameters in REMS*		
Variable	**OR**	**95% CI**	***p*-Value**
GCS	0.743	0.711, 0.777	<0.0001
O_2 Saturation (%)	0.961	0.940, 0.982	0.0004
Age (yrs)	1.034	1.024, 1.044	<0.0001
MAP	0.979	0.973, 0.986	<0.0001
HR (beats/min)	0.996	0.990, 1.002	0.2179
RR (breaths/min)	1.001	0.978, 1.025	0.9023

Table 6	*Blunt vs. Penetrating Mortality 3,680 Trauma Patients*			
REMS	**Blunt Mortality (%)**	**Penetrating Mortality (%)**	***p*-Value**	**Overall Mortality (%)**
0-2	0.3%	0.5%	0.6375	0.3%
3-5	1.7%	3.0%	0.2542	2.0%
6-9	5.6%	14.9%	0.0082	6.7%
10-11	15.5%	45.4%	0.0031	20.3%
12-13	29.7%	46.7%	0.2329	32.9%
14-15	41.7%	75.0%	0.3100	45.0%
16-19	75.0%	92.3%	0.3983	24.2%
20-21	85.7%	100.0%	1.0000	92.9%
22-26	100.0%	100.0%		100.0%
Total	4.4%	8.0%	<0.0001	5.2%

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Authors' Contributions

BI participated in designing and coordinating the execution of the study, conducted the chart review, and drafting the manuscript. NT participated in designing and coordinating the execution of the study, and drafting the manuscript. MH participated in coordinating the execution of the study. NN performed the statistical analysis. MM participated in the design of the study and drafting the manuscript. CC participated in the design of the study and drafting the manuscript. All authors read and approved the manuscript.

Competing Interests

The author(s) declare that they have no competing interests.

Data Sharing

No additional data

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Injury Severity Score (ISS), Rapid Emergency Medicine Score (REMS), Revised Trauma Score (RTS), Trauma, Triage, Shock Index (SI)

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ABSTRACT

Objectives: REMS is an attenuated version of the Acute Physiology and Chronic Health Evaluation (APACHE) II score and has utility in predicting mortality in non-surgical patients, but has yet to be tested among the trauma population. The objective is to evaluate REMS as a risk stratification tool for predicting in-hospital mortality in traumatically-injured patients and to compare REMS accuracy in predicting mortality to existing trauma scores, including the Revised Trauma Score (RTS), Injury Severity Score (ISS), and Shock Index (SI).

Design and Setting: Retrospective chart review of the trauma registry from an urban academic American College of Surgeons (ACS) Level 1 trauma center.

Participants: 3,680 trauma patients aged 14 years and older admitted to the hospital over a four-year period. Patients transferred from other hospitals were excluded from the study as were those who suffered from burn or drowning-related injuries. Patients with vital sign documentation insufficient to calculate a REMS score were also excluded.

Primary outcome measures: The predictive ability of REMS was evaluated using odds ratios for in-hospital mortality. The discriminate power of REMS, RTS, ISS, and SI was compared using the area under the receiver operating characteristic curve.

Results: Higher REMS was associated with increased mortality ($p < 0.0001$). An increase of 1 point in the 26-point REMS scale was associated with an odds ratio of 1.51 for in-hospital death (95% CI 1.45 - 1.58). REMS (AUC 0.91 ± 0.02) was found to be similar to RTS (AUC 0.89 ± 0.04) and superior to ISS (AUC 0.87 ± 0.01), and SI (AUC 0.55 ± 0.31) in predicting in-hospital mortality.

Conclusions: In the trauma population, REMS appears to be a simple, accurate predictor of in-hospital mortality. While REMS performed similarly to RTS in predicting mortality, it did outperform other traditionally used trauma scoring systems, specifically ISS and SI.

Strengths & Limitations

- This is the first study to demonstrate the applicability of REMS, a more rapid and less invasive version of the APACHE II score, to traumatically-injured patients.
- REMS, which is calculated from readily-available parameters, performs favorably in comparison to existing trauma scores to predict in-hospital mortality.
- While the study analyzed a large sample size at a single urban academic trauma center, attempts to extrapolate results to other trauma populations may not be reliable.
- REMS was originally derived from the medicine population, therefore the scoring system does not differentiate between injury types, which are known factors in predicting mortality.
- The expertise of the treating trauma center will influence patient outcomes, therefore impact the REMS-mortality relationship. This however is a limitation of all scoring systems and is not unique to REMS alone.

Introduction

Trauma and unintentional injury is the leading cause of death for all individuals less than 44 years of age which results in a major cost burden for the health care system.[1] Current literature supports that early diagnosis and appropriate treatment both improve outcomes and are cost effective. Over the past decade, scoring systems have been utilised to assess injury severity and provide an objective measure for treatment and appropriate allocation of health care resources. The Acute Physiology and Chronic Health Evaluation (APACHE II) is a validated scale that assesses severity of illness among, non-surgical, surgical, and intensive care hospital patients.[2] The score incorporates body temperature, respiratory rate (RR), heart rate (HR), mean arterial pressure (MAP), oxygenation of arterial blood, arterial pH, serum sodium and potassium levels, serum creatinine, hematocrit, white blood cell count, and GCS.[3] With a reliance on laboratory tests such as blood chemistry analysis, APACHE II scoring remains impractical for rapid injury severity assessment required in the emergency department (ED) or in the field. The Rapid Emergency Medicine Score (REMS), an attenuated version of APACHE II, allows for prompt calculation.[2, 4] REMS is a composite score consisting of the Glasgow Coma Scale (GCS), RR, oxygen saturation, MAP, HR and age.[5] Among non-surgical patients who present to the ED, REMS has proven to be a valid predictor of mortality.

While many ED scoring methodologies focus on evaluating short-term outcomes, REMS has been shown to predict mortality at one week (HR 1.34, 95% CI 1.30-1.37), one month (HR 1.30, 95% CI 1.27-1.32) and three months (HR 1.26, 95% CI 1.24-1.28).[2] An additional study comparing area under the receiver operating curve (AUC) for the Rapid Acute Physiology Score (0.64, 95% CI 0.59-0.69) and REMS (0.74, 95% CI 0.70-0.78) in non-surgical ED patients determined superiority of the REMS.[5, 6] Every point increase in the 26-point REMS score was associated with an odds ratio (OR) of 1.40 (95% CI 1.36-1.45, $p < 0.0001$) for in-hospital mortality.[5] While there have been extensive publications reporting sound predicative validity for this score among non-surgical patients, the utility of REMS in the trauma population has yet to be analyzed.

The purpose of this study was to evaluate REMS as a risk stratification tool to predict in-hospital mortality in traumatically injured patients. Secondary objectives included comparing REMS to the Revised Trauma Score (RTS), the Injury Severity Score (ISS), and the Shock Index (SI) to determine which scoring system was a superior predictor of mortality, in addition to examining the six components of REMS to determine which, if any, were most predictive of mortality.

Materials and Methods

<u>Study Design</u>: This was a retrospective chart review of the trauma registry at an urban academic American College of Surgeons (ACS) Level 1 trauma center. The study was reviewed by the hospital institutional review board, The University of Kansas Medical Center Human Subjects Committee, and a waiver of informed consent was granted.

<u>Study Population</u>: Analysis focused on 3,680 trauma patients aged 14 years and older admitted to the hospital over a four-year period. Patients transferred from other hospitals were excluded from the study; for these patients, vital signs may have changed from initial values due to treatment at institution, affecting REMS calculations. Patients who suffered from burn or drowning-related injuries were also excluded from

the study. Finally, 158 patients with vital sign documentation that was insufficient for REMS calculation were also excluded. 47 patients were missing non-REMS injury scores (i.e. SI, ISS, RTS); these patients were included in all the REMS analyses except calculation of the AUC for their respective scoring systems.

Protocol: Variables collected included age, date and time of arrival, race, sex, systolic blood pressure (SBP), diastolic blood pressure (DBP), RR, HR, oxygen saturation, length of stay, and GCS. The ISS and RTS scores were calculated by and obtained from the trauma registry. The mean arterial pressure (MAP) and SI (HR divided by SBP) were calculated during data analysis.

Measurements: REMS scoring requires RR, HR, MAP, GCS, age and oxygen saturation.[5] In REMS calculation, age is assigned a value from 0 to 6, and the remaining five variables are each assigned a score from 0 to 4 (Table 1). REMS is a sum of these values with a maximum composite score of 26, with higher values being indicative of worse prognosis.

In this study, REMS was compared to three currently utilised injury scoring systems, including SI, ISS and RTS, to determine which measure was superior in predicting mortality. SI is calculated by dividing heart rate by systolic blood pressure and has proven useful in predicting mortality and the severity of illness in traumatically ill patients.[7, 8] Likewise, the ISS correlates with mortality. In contrast, the ISS is an anatomically-based scoring system based on injuries to major body regions including the head and neck, face, chest, abdomen and pelvic contents, extremities and pelvic girdle and external.[9, 10] The ISS is useful for assessment following motor vehicle collisions. The ISS algorithm incorporates points from each region with a maximum score of 75 (higher values represent more serious trauma). Finally, the RTS can be used by pre-hospital emergency personnel to assist with triage of injured patients. The variables include RR, SBP, and GCS[11], and the un-weighted RTS is calculated by adding the values assigned for each parameter against a maximum possible score of twelve.

Data Analysis: Continuous variables are described using mean and standard deviation. Similarly, categorical variables are described using frequency and percentage. Parametric tests were used for the comparisons between groups: Chi-square test in the case of categorical variables and the t-test in the case of continuous variables. Correlations were tested using Spearman test. Sensitivity and specificity were plotted using the receiver operating characteristic (ROC) curve. The discriminate power of REMS, RTS, ISS, and SI was compared using the AUC. Statistically significant associations and differences were identified by *p*-values of less than 0.05. All analyses were conducted using SAS version 9.3 (copyright© 2002–2008 by SAS Institute Inc., Cary, NC, USA).

Results

Of the patients studied, 3,489 (94.8%) lived and 191 (5.2%) died. Characteristics of the study sample are included in Table 2. Patients who lived had a mean age of 36.5 ± 17.0 years, 73.7% were male, 62.5% were Caucasian, the average REMS was 3.4 (± 3.2) and the average length of stay was 7.6 (± 15.4) days. Patients who died had a mean age of 43.7 years, 77.0% were male, 59.2% were Caucasian, the average REMS was 11.8, and the average length of stay was 4.4 days.

The study team looked at the distribution of patient mortality by each incremental REMS score (1-26). Based on this distribution, the authors used natural cutoffs as well as their clinical judgment to develop the REMS groupings used in the study. A higher REMS was associated with increased mortality ($p < 0.0001$, Table 3). Patients with REMS less than 6, from 6 to 9 and greater than 9 had mortalities of 0.9%, 6.7% and 39.3%, respectively. An increase of one point within the 26-point REMS was associated with an OR of 1.51 for in-hospital death (95% CI 1.45 to 1.58).

Patients with low REMS scores who died presented to the ED with lower median GCS than those who survived. The median GCS for patients with REMS of 3 to 5 and 6 to 9 who died was 1.5 ($p < 0.0001$) and 8 ($p < 0.0001$) points lower than those who lived. Patients with high REMS scores who lived presented to the ED with a higher median age than those who died. The median age for patients with REMS of 16 to 19 and 20 to 21 who lived was 45.5 ($p = 0.01$) and 50 ($p = 0.13$) years older than those who died.

Secondarily, REMS was compared to three additional injury severity scoring systems (Table 4). REMS (AUC 0.91 ± 0.02) was found to be similar to RTS (AUC 0.89 ± 0.04) and superior to ISS (AUC 0.87 ± 0.01), and SI (AUC 0.55 ± 0.31) in predicting in-hospital mortality (Figure 1). The mean SI for patients that lived was 0.69 (± 0.22) and 0.79 (± 0.40) for those who died. The mean RTS for patients that lived was 7.4 (± 1.3) and 3.5 (± 2.7) for those who died. Lastly, the mean ISS score for patients that lived was 11.3 (± 10.0) and 30.0 (± 14.6) for those who died.

While multivariable logistic regression indicated that HR and RR individually did not predict mortality, the other four REMS parameters did (Table 5). GCS was the strongest predictor of mortality (OR 0.743, 95% CI 0.71 to 0.78). While not directly assessed by REMS, injury type also impacts patient mortality rates (Table 6). Patients with penetrating trauma experienced higher mortality rates than those with blunt force trauma (8.0% versus 4.4%, $p < 0.0001$).

Discussion

Despite recent improvements in trauma systems and their resulting decrease in preventable deaths, trauma continues to be the leading cause of mortality for those under the age of 44 years in the United States.[12] Trauma systems rely on imperfect and subjective tools to triage critically injured patients to the appropriate center. Currently, emergency medical service (EMS) and trauma care providers utilise a variety of factors such as blood pressure, RR, GCS, as well as mechanism of injury to prioritise responses and resources. With increasing rates of ED and trauma diversion, particularly in urban settings, efficient allocation of resources is more crucial than ever.[13] Organised and inclusive trauma systems depend on patients being routed to the closest and most appropriate center capable of caring for the patient. Any tool that can match true severity with the highest possible resource within the system may ensure that higher level centers are able to concentrate on patients most in need of their capabilities. In particular, REMS appears to provide an effective balance between the predictive ability and the practical application which are necessary for the trauma setting. Unlike systems used elsewhere in the hospital, REMS does not require invasive or time-consuming lab values such as lactate, base deficit, mixed venous oxygen saturation, or cutaneous tissue oxygen saturation.[14-19] Rather, REMS utilises readily available parameters available both in the pre-hospital environment and in the ED.

The current body of literature related to REMS examines its application among non-surgical medicine patients. Studies conducted by Olsson et al., have concluded that use of the REMS among non-surgical patients in the ED is powerful in predicting both in-hospital and long-term mortality. In their studies, their research showed that all six REMS parameters were predictive of mortality. Similarly, Goodcare et al., found REMS to be effective in predicting mortality amongst medicine patients, although, age, GCS, and oxygen saturation were the only REMS parameters that strongly correlated with mortality. Our study indicates that applying REMS to the trauma population yields similar results and that REMS is a strong predictor of mortality.

It is important to note that REMS, like other trauma scoring methods, was originally devised using population-level data. Applying REMS at the individual patient level yields an estimated mortality percentage; because actual outcomes are binary (i.e. alive or dead), it would not be unexpected to for a limited number of patients with low REMS to die and those with high REMS to live.

In this study, REMS performed similar to or better than all other measures in predicting mortality. ISS was nearly as predictive of mortality but is a retrospective system whose score can only be determined after diagnosis. ISS is therefore better suited as a benchmark for comparison (between patient groups or trauma centers) and not practically useful as a triage tool. While SI, which is calculated using two readily available vitals (HR and SBP), is both simple and fast to utilise, it severely underperformed REMS in predicting mortality. Un-weighted RTS was found to be the most effective alternative to REMS as a triage tool; its strength in predicting mortality was similar to that of REMS, but RTS uses only a subset of REMS measures (GCS, SBP and RR) and a 0 to 4 point scale for each variable. When compared to REMS, RTS substitutes a small amount of predictive ability in return for simplicity.

This study expands the usefulness of REMS in the ED, demonstrating its capability for predicting mortality in the trauma population. However, since REMS components and values were derived using data from a medicine population, further analysis of the applicability to a trauma population may be beneficial. Underlying reasons may include that medicine patients are more likely to have chronic comorbidities that may contribute to differing baseline vitals leading to a score variation. In addition, medicine patients may have a greater portion of their score attributable to age in comparison to that of the trauma population, which often consists of younger, otherwise healthy adults. Similar to Goodcare et al., this study found that the REMS components correlated with mortality were GCS, oxygen saturation, age, and MAP; of those, GCS was found to have the strongest predictor of mortality among the trauma population, while HR and RR did not exhibit any statistically significance.

Analysis suggests that GCS may be underweighted in the REMS calculation for trauma patients. At the lower end of the REMS scale (scores of 3 to 5 and 6 to 9), patients who died presented with a lower average GCS than those who lived. For REMS of 3 to 5, the average GCS for those who died was 11.1 (9 to 12 is classified as a moderate head injury[20]) compared to 14.2 (13 to 15 is classified as a mild head injury) for those who lived. For REMS of 6 to 9, the average GCS for those who died was 8.4 (≤ 8 is classified as a severe head injury) compared to 11.5 (moderate head injury) for those who lived. In a study of geriatric trauma, Champion et al., found a difference in mortality between trauma patients older than 65 (19.0%) and those younger than 65 (9.8%).[21] This difference in mortality may be due to the factor of age and the weight it carries within the REMS calculation methodology. However, our findings suggest that age may be over-weighted in the REMS calculation for trauma patients. At the higher end of the REMS scale (scores of 16 to 19 and 20 to 21), patients who survived presented with a greater average age; in these cases, a greater portion of the composite REMS score came from age.

REMS was derived from the medicine population; as a result, the scoring system does not differentiate between injury types. For the trauma population, however, injury type is a significant factor in mortality prediction. A significant difference in average mortality rates was demonstrated in patients presenting with blunt (4.4%) versus penetrating (8.0%) injury types. Differences in mortality rates by injury type persist at all levels of REMS.

This study, which analyzed a large number of trauma patients within a single hospital system, does possess several limitations. First, this was a retrospective analysis. As with any such study, potential disadvantages include the possibility of selection bias. Second, the study excluded 158 potential records from the analysis due to missing patient data required to calculate REMS. 47 patients were excluded from the calculation of the due to missing non-REMS injury scores (i.e. RTS, ISS, SI). Finally, because the study is based on data from a single urban academic ACS Level 1 trauma center, attempts to extrapolate results to other trauma populations may not be reliable. Given the focused population, opportunities exist for future expansion and improvement, such as conducting a prospective study on the predictive capability of REMS on mortality, and using a larger, more diverse trauma dataset. Evaluating REMS in the pre-hospital setting and monitoring the change in REMS from initial EMS contact to trauma center arrival may prove to be useful for EMS and for the ED by enhancing the effectiveness of the triage process, the appropriate routing of patients, and the utilization of trauma resources.

Conclusions

Though initially designed for the medicine population, REMS was found to be a strong predictor of in-hospital mortality for the trauma population. REMS performed similarly to RTS and outperformed several other traditionally-used trauma scales including ISS, and SI. This study also indicates potential opportunities to better apply REMS to the trauma population. REMS components HR and RR were found to have no statistically significant contribution in mortality prediction, while age and GCS were over- or under-weighted in the REMS calculation, respectively. Injury type is an important predictor of mortality in trauma patients, and it was not included in the REMS calculation. Each of these represents an opportunity for future study.

Key Messages

- REMS is a more rapid and less invasive form of APACHE II, utilizing age, blood pressure, HR, GCS, RR, and peripheral oxygen saturation
- REMS performed similarly to RTS in the trauma population but was a better predictor of mortality than ISS or SI

- Age, MAP, oxygen saturation and GCS correlate with mortality, with GCS exhibiting the strongest correlation

List of Abbreviations

APACHE: Acute Physiology and Chronic Health Evaluation

AUC: Area under Receiver Operator Characteristic (ROC) Curve

CI: Confidence Interval

DBP: Diastolic Blood Pressure

ED: Emergency Department

EMS: Emergency Medical Service

GCS: Glasgow Coma Score

HR: Heart Rate

ISS: Injury Severity Score

MAP: Mean Arterial Pressure

OR: Odds Ratio

REMS: Rapid Emergency Medicine Score

ROC: Receiver Operator Characteristic

RR: Respiratory Rate

RTS: Revised Trauma Score

SBP: Systolic Blood Pressure

SI: Shock Index

Tables and Captions

Table 1 *REMS Scoring System*

	Score						
Variable	0	+1	+2	+3	+4	+5	+6
Age (years)	<45		45-54	55-64		65-74	>74
MAP	70-109		110-129 50-69	130-159	>159 ≤ 49		
HR (beats/min)	70-109		110-139 55-69	140-179 40-54	>179 ≤39		
RR (breaths/min)	12-24	25-34 10-11	6-9	35-49	>49 ≤ 5		
O_2 Saturation (%)	>89	86-89		75-85	<75		
GCS	14 or 15	11-13	8-10	5-7	3 or 4		

Table 2 ***Baseline Characteristics and Hospital Course for 3,680 Trauma Patients***

	Dead (N=191) Mean (SD)*	Alive (N=3,489) Mean (SD)*	*p*-Value
Age (years)	43.7 (21.0)	36.5 (17.0)	<0.0001
Male (%)	77.0	73.7	0.0472
Race (%)			0.0564
White	59.2	62.4	
Black	23.5	23.2	
Other	17.3	14.4	
Length of Stay (days)	4.4 (8.0)	7.6 (15.2)	0. 0043
Systolic BP (mmHg)	104.1 (68.3)	142.5 (24.9)	<0.0001
Diastolic BP (mmHg)	61.1 (43.6)	84.6 (20.5)	<0.0001
HR (beats/min)	76.0 (49.7)	95.7 (20.7)	<0.0001
RR (breaths/min)	8.0 (11.0)	18.0 (6.8)	<0.0001
O_2 Saturation (%)	86.1 (30.2)	98.1 (3.8)	<0.0001
GCS	5.8 (4.6)	13.6 (3.4)	<0.0001

* Except where noted as %.

Table 3 ***REMS Score Characteristics*** ($p < 0.0001$) ***3,680 Trauma Patients***

REMS	Alive (N)	Dead (N)	Mortality
0-2	1749	6	0.3%
3-5	999	20	2.0%
6-9	547	39	6.7%

10-11	110	28	20.3%
12-13	53	26	32.9%
14-15	22	18	45.0%
16-19	8	33	80.5%
20-21	1	13	92.9%
22-26	0	8	100.0%
Total	3489	191	5.2%

Table 4 ***Injury Scores for 3,680 Trauma Patients***

	N	**Dead Mean (SD)**	**Alive Mean (SD)**	***p*-Value**
REMS Score	3,680	11.8 (5.4)	3.4 (3.2)	<0.0001
SI	3,633	0.79 (0.40)	0.69 (0.22)	<0.0001
RTS	3,680	3.5 (2.7)	7.4 (1.3)	<0.0001
ISS	3,671	30.0 (14.6)	11.3 (10.0)	<0.0001

Table 5 ***Multiple Logistic Regression for All Parameters in REMS***

Variable	**OR**	**95% CI**	***p*-Value**
GCS	0.743	0.711, 0.777	<0.0001
O_2 Saturation (%)	0.961	0.940, 0.982	0.0004
Age (yrs)	1.034	1.024, 1.044	<0.0001
MAP	0.979	0.973, 0.986	<0.0001
HR (beats/min)	0.996	0.990, 1.002	0.2179
RR (breaths/min)	1.001	0.978, 1.025	0.9023

Table 6 ***Blunt vs. Penetrating Mortality 3,680 Trauma Patients***

REMS	**Blunt Mortality**	**Penetrating Mortality**	***p*-Value**	**Overall Mortality**
0-2	0.3%	0.5%	0.6375	0.3%
3-5	1.7%	3.0%	0.2542	2.0%
6-9	5.6%	14.9%	0.0082	6.7%
10-11	15.5%	45.4%	0.0031	20.3%
12-13	29.7%	46.7%	0.2329	32.9%
14-15	41.7%	75.0%	0.3100	45.0%
16-19	75.0%	92.3%	0.3983	80.5%
20-21	85.7%	100.0%	1.0000	92.9%
22-26	100.0%	100.0%		100.0%
Total	4.4%	8.0%	<0.0001	5.2%

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Authors' Contributions

BI participated in designing and coordinating the execution of the study, conducted the chart review, and drafting the manuscript. NT participated in designing and coordinating the execution of the study, and drafting the manuscript. MH participated in coordinating the execution of the study. NN performed the statistical analysis. MM participated in the design of the study and drafting the manuscript. CC participated in the design of the study and drafting the manuscript. All authors read and approved the manuscript

Competing Interests

The author(s) declare that they have no competing interests.

Data Sharing Statement

No additional data are available

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Rapid Emergency Medicine Score (REMS) in the Trauma Population: A Retrospective Study

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Primary outcome measures: The predictive ability of REMS was evaluated using odds ratios for in-hospital mortality. The discriminate power of REMS, RTS, ISS, and SI was compared using the area under the receiver operating characteristic curve.

Results: Higher REMS was associated with increased mortality ($p < 0.0001$). An increase of 1 point in the 26-point REMS scale was associated with an odds ratio of 1.51 for in-hospital death (95% CI 1.45 - 1.58). REMS (AUC 0.91 ± 0.02) was found to be similar to RTS (AUC 0.89 ± 0.04) and superior to ISS (AUC 0.87 ± 0.01), and SI (AUC 0.55 ± 0.31) in predicting in-hospital mortality.

Conclusions: In the trauma population, REMS appears to be a simple, accurate predictor of in-hospital mortality. While REMS performed similarly to RTS in predicting mortality, it did outperform other traditionally used trauma scoring systems, specifically ISS and SI.

Introduction

Trauma and unintentional injury is the leading cause of death for all individuals less than 44 years of age which results in a major cost burden for the health care system.[1] Current literature supports that early diagnosis and appropriate treatment both improve outcomes and are cost effective. Over the past decade, scoring systems have been utilised to assess injury severity and provide an objective measure for treatment and appropriate allocation of health care resources. The Acute Physiology and Chronic Health Evaluation (APACHE II) is a validated scale that assesses severity of illness among, non-surgical, surgical, and intensive care hospital patients.[2] The score incorporates body temperature, respiratory rate (RR), heart rate (HR), mean arterial pressure (MAP), oxygenation of arterial blood, arterial pH, serum sodium and potassium levels, serum creatinine, hematocrit, white blood cell count, and GCS.[3] With a reliance on laboratory tests such as~~Calculation of an APACHE II score requires~~ blood chemistry analysis, APACHE II scoring remains ~~which renders this score~~ impractical for ~~the~~ rapid injury severity ~~scoring~~ assessment ~~necessary~~ required in the emergency department (ED) or in the field. The Rapid Emergency Medicine Score (REMS), an attenuated version of APACHE II, allows for prompt calculation.~~[2, 3]~~[2, 4] REMS is a composite score consisting of the Glasgow Coma Scale (GCS), ~~respiratory rate (RR)~~RR, oxygen saturation, ~~blood pressure~~MAP, ~~heart rate (HR)~~HR and age.~~[4]~~[5] Among non-surgical patients who present to the ED, REMS has proven to be a valid predictor of mortality.

While many ED scoring methodologies focus on evaluating short-term outcomes, REMS has been shown to predict mortality at one week (HR 1.34, 95% CI 1.30-1.37), one month (HR 1.30, 95% CI 1.27-1.32) and three months (HR 1.26, 95% CI 1.24-

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1.28).[2] An additional study comparing area under the receiver operating curve (AUC) for the Rapid Acute Physiology Score (0.64, 95% CI 0.59-0.69) and REMS (0.74, 95% CI 0.70-0.78) in non-surgical ED patients determined superiority of the REMS.[~~4, 5~~5, 6] Every point increase in the 26-point REMS score was associated with an odds ratio (OR) of 1.40 (95% CI 1.36-1.45, p < 0.0001) for in-hospital mortality.[4–5] While there have been extensive publications reporting sound predicative validity for this score among non-surgical patients, the utility of REMS in the trauma population has yet to be analyzed.

The purpose of this study was to evaluate REMS as a risk stratification tool to predict in-hospital mortality in traumatically injured patients. Secondary objectives included comparing REMS to the Revised Trauma Score (RTS), the Injury Severity Score (ISS), and the Shock Index (SI) to determine which scoring system was a superior predictor of mortality, in addition to examining the six ~~parameters~~ components of REMS to determine which, if any, were most predictive of mortality.

Materials and Methods

Study Design: This was a retrospective chart review of the trauma registry at an urban academic American College of Surgeons (ACS) Level 1 trauma center. The study was reviewed by the hospital institutional review board, The University of Kansas Medical Center Human Subjects Committee, and a waiver of informed consent was granted.

Study Population: Analysis focused on 3,680 trauma patients aged 14 years and older admitted to the hospital over a four-year period. Patients transferred from other hospitals were excluded from the study; for these patients, vital signs may have changed from initial values due to treatment at institution, affecting REMS calculations.

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Patients who suffered from burn or drowning-related injuries were also excluded from the study. Finally, 158 patients with vital sign documentation that was insufficient for REMS calculation were also excluded. 47 patients were missing non-REMS injury scores (i.e. SI, ISS, RTS); these patients were included in all the REMS analyses except calculation of the AUC for their respective scoring systems.

Protocol: Variables collected included age, date and time of arrival, race, sex, systolic blood pressure (SBP), diastolic blood pressure (DBP), RR, HR, oxygen saturation, length of stay, and GCS. The ISS and RTS scores were calculated by and obtained from the trauma registry. The mean arterial pressure (MAP) and SI (HR divided by SBP) were calculated during data analysis.

Measurements: ~~The APACHE II score is utilised to classify disease severity in the hospital setting, incorporating body temperature, RR, HR, MAP (calculated with SBP and DBP), oxygenation of arterial blood, arterial pH, serum sodium and potassium levels, serum creatinine, hematocrit, white blood cell count, and GCS.~~[6] REMS scoring requires ~~preserves the more readily-obtained vital signs (~~RR, HR, MAP, GCS~~) while also considering~~, age and oxygen saturation.[4–5] In REMS calculation, age is assigned a value from 0 to 6, and the remaining five variables are each assigned a score from 0 to 4 (Table 1). REMS is a sum of these values with a maximum composite score of 26, with higher values being indicative of worse prognosis.

In this study, REMS was compared to three currently utilised injury scoring systems, including SI, ISS and RTS, to determine which measure was superior in predicting mortality. SI is calculated by dividing heart rate by systolic blood pressure and has proven useful in predicting mortality and the severity of illness in traumatically ill

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patients.[7, 8] Likewise, the ISS correlates with mortality. In contrast, the ISS is an anatomically-based scoring system based on injuries to major body regions including the head and neck, face, chest, abdomen and pelvic contents, extremities and pelvic girdle and external.[9, 10] The ISS is useful for assessment following motor vehicle collisions. The ISS algorithm incorporates points from each region with a maximum score of 75 (higher values represent more serious trauma). Finally, the RTS can be used by pre-hospital emergency personnel to assist with triage of injured patients. The variables include RR, SBP, and GCS~~,~~[11], and the un-weighted RTS is calculated by adding the values assigned for each parameter against a maximum possible score of ~~12~~twelve.

Data Analysis: Continuous variables ~~were~~ are described using mean and standard deviation. Similarly, categorical variables ~~were~~ are described using frequency and percentage. Parametric tests were used for the comparisons between groups: Chi-square test in the case of categorical variables and the t-test in the case of continuous variables. Correlations were tested using Spearman test. Sensitivity and specificity were plotted using the receiver operating characteristic (ROC) curve. The discriminate power of REMS, RTS, ISS, and SI was compared using the AUC. Statistically significant associations and differences were identified by *p*-values of less than 0.05. All analyses were conducted using SAS version 9.3 (copyright© 2002–2008 by SAS Institute Inc., Cary, NC, USA).

Results

Of the patients studied, 3,489 (94.8%) lived and 191 (5.2%) died. Characteristics of the study sample are included in Table 2. Patients who lived had a mean age of 36.5 ± 17.0 years, 73.7% were male, 62.5% were Caucasian, the average REMS was 3.4 (± 3.2) and the average length of stay was 7.6 (± 15.4) days. Patients who died had a mean age of 43.7 years, 77.0% were male, 59.2% were Caucasian, the average REMS was 11.8, and the average length of stay was 4.4 days.

The study team looked~~created~~ at the distribution of patient mortality by each incremental REMS score (1-26). Based on this distribution, the authors used natural cutoffs as well as their clinical ~~judgement~~judgment~~a team of ER physicians used their clinical judgment as well as natural cutoffs~~ to develop the REMS groupings used in the study. A higher REMS was associated with increased mortality (p < 0.0001, Table 3). Patients with REMS less than 6, from 6 to 9 and greater than 9 had mortalities of 0.9%, 6.7% and 39.3%, respectively. An increase of one point within the 26-point REMS was associated with an OR of 1.51 for in-hospital death (95% CI 1.45 to 1.58).

Patients with low REMS scores who died presented to the ED with lower median GCS than those who survived. The median GCS for patients with REMS of 3 to 5 and 6 to 9 who died was 1.5 (p < 0.0001) and 8 (p < 0.0001) points lower than those who lived. Patients with high REMS scores who lived presented to the ED with a higher median age than those who died. The median age for patients with REMS of 16 to 19 and 20 to 21 who lived was 45.5 (p = 0.01) and 50 (p = 0.13) years older than those who died.

Secondarily, REMS was compared to three additional injury severity scoring systems (Table 4). REMS (AUC 0.91 ± 0.02) was found to be ~~superior~~ similar to RTS

(AUC 0.89 ± 0.04) and superior to~~,~~ ISS (AUC 0.87 ± 0.01), and SI (AUC 0.55 ± 0.31) in predicting in-hospital mortality (Figure 1). The mean SI for patients that lived was 0.69 (± 0.22) and 0.79 (± 0.40) for those who died. The mean RTS for patients that lived was 7.4 (± 1.3) and 3.5 (± 2.7) for those who died. Lastly, the mean ISS score for patients that lived was 11.3 (± 10.0) and 30.0 (± 14.6) for those who died.

While multivariable logistic regression indicated that HR and RR individually did not predict mortality, the other four REMS parameters did (Table 5). GCS was the strongest predictor of mortality (OR 0.743, 95% CI 0.71 to 0.78). While not directly assessed by REMS, injury type also impacts patient mortality rates (Table 6). Patients with penetrating trauma experienced higher mortality rates than those with blunt force trauma (8.0% versus 4.4%, $p < 0.0001$).

Discussion

Despite recent improvements in trauma systems and their resulting decrease in preventable deaths, trauma continues to be the leading cause of mortality for those under the age of 44 years in the United States.[12] Trauma systems rely on imperfect and subjective tools to triage critically injured patients to the appropriate center. Currently, emergency medical service (EMS) and trauma care providers utilise a variety of factors such as blood pressure, RR, GCS, as well as mechanism of injury to prioritise~~d~~ responses and resources. With increasing rates of ED and trauma diversion, particularly in urban settings, efficient allocation of resources is more crucial than ever.[13] Organised and inclusive trauma systems depend on patients being routed to the closest and most appropriate center capable of caring for the patient. Any tool that can match true severity with the highest possible resource within the system may ensure that higher level centers are able to concentrate on patients most in need of their capabilities.[22-25] In particular, REMS appears to provide an effective balance between the predictive ability and the practical application which are necessary for the trauma setting. Unlike systems used elsewhere in the hospital, REMS does not require invasive or time-consuming lab values such as lactate, base deficit, mixed venous oxygen saturation, or~~and~~ cutaneous tissue oxygen saturation.[14-19] Rather, REMS utilises readily available parameters available both in the pre-hospital environment and in the ED.

The current body of literature related to REMS examines its application among non-surgical medicine patients. Studies conducted by Olsson et al., have concluded that use of the REMS among non-surgical patients in the ED is powerful in predicting both in-hospital and long-term mortality. In their studies, their research showed that all six REMS parameters were predictive of mortality. Similarly, Goodcare et al., found REMS to be effective in predicting mortality amongst medicine patients, although, age, GCS, and oxygen saturation were the only REMS parameters that strongly correlated with mortality. Our study indicates that applying REMS to the trauma population yields similar results and that REMS is a strong predictor of mortality.

It is important to note that REMS, like other trauma scoring methods, was originally devised using population-level data. Applying REMS at the individual patient level yields an estimated mortality percentage; because actual outcomes are binary (i.e. alive or dead), it would not be unexpected to for a ~~very~~ limited number of patients with low REMS to die and those with high REMS to live.

In this study, REMS ~~out~~performed similar to or better than all other measures in predicting mortality. ISS was nearly as predictive of mortality but is a retrospective system whose score can only be determined after diagnosis. ISS is therefore better suited as a benchmark for comparison (between patient groups or trauma centers) and not practically useful as a triage tool. While SI, which is calculated using two readily available vitals (HR and SBP), is both simple and fast to utilise, it severely underperformed REMS in predicting mortality. Un-weighted RTS was found to be the most effective alternative to REMS as a triage tool; its strength in predicting mortality was similar to that of REMS, but RTS uses only a subset of REMS measures (GCS, SBP and RR) and a 0 to 4 point scale for each variable. When compared to REMS, RTS ~~affords~~ substitutes a small amount of predictive ability in return for simplicity.

This study expands the usefulness of REMS in the ED, demonstrating its capability for predicting mortality in the trauma population. However, since REMS components and values were derived using data from a medicine population, further analysis of the applicability to a trauma population may be beneficial. Underlying reasons may include that medicine patients are more likely to have chronic comorbidities that may contribute to differing baseline vitals leading to a score variation. In addition, medicine patients may have a greater portion of their score attributable to age in comparison to that of the trauma population, which often consists of younger, otherwise healthy adults. Similar to Goodcare et al., this study found that the REMS components correlated with mortality were GCS, oxygen saturation, age, and MAP; of those, GCS was found to have the strongest predictor of mortality among the trauma population, while HR and RR did not exhibit any statistically significance.

Analysis suggests that GCS may be underweighted in the REMS calculation for trauma patients. At the lower end of the REMS scale (scores of 3 to 5 and 6 to 9), patients who died presented with a lower average GCS than those who lived. For REMS of 3 to 5, the average GCS for those who died was 11.1 (9 to 12 is classified as a moderate head injury[20]) compared to 14.2 (13 to 15 is classified as a mild head injury) for those who lived. For REMS of 6 to 9, the average GCS for those who died was 8.4 (≤ 8 is classified as a severe head injury) compared to 11.5 (moderate head injury) for those who lived. In a study of geriatric trauma, Champion et al., found a difference in mortality between trauma patients older than 65 (19.0%) and those younger than 65 (9.8%).[21] This difference in mortality may be due to the factor of age and the weight it carries within the REMS calculation methodology. However, our findings suggest that age may be over-weighted in the REMS calculation for trauma patients. At the higher end of the REMS scale (scores of 16 to 19 and 20 to 21), patients who survived presented with a greater average age; in these cases, a greater portion of the composite REMS score came from age.

REMS was derived from the medicine population; as a result, the scoring system does not differentiate between injury types. For the trauma population, however, injury type is a significant factor in mortality prediction. A significant difference in average mortality rates was demonstrated in patients presenting with blunt (4.4%) versus penetrating (8.0%) injury types. Differences in mortality rates by injury type persist at all levels of REMS.

This study, which analyzed a large number of trauma patients within a single hospital system, does possess several limitations. First, this was a retrospective analysis. As with any such study, potential disadvantages include the possibility of selection bias. Second, the study excluded 158 potential records from the analysis due to missing patient data required to calculate REMS. 47 patients were excluded from the calculation of the due to missing non-REMS injury scores (i.e. RTS, ISS, SI). Finally, because the study is based on data from a single urban academic ACS Level 1 trauma center, attempts to extrapolate results to other trauma populations may not be reliable. Given the focused population, opportunities exist for future expansion and improvement, such as conducting a prospective study on the predictive capability of REMS on mortality, and using a larger, more diverse trauma dataset. Evaluating REMS in the pre-hospital setting and monitoring the change in REMS from initial EMS contact to trauma center arrival may prove to be useful for EMS and for the ED by enhancing the effectiveness of the triage process, the appropriate routing of patients, and the utilization of trauma resources.

Conclusions

Though initially designed for the medicine population, REMS was found to be a strong predictor of in-hospital mortality for the trauma population. REMS performed similarly to RTS and outperformed several other traditionally-used trauma scales including ISS, and SI. ~~REMS outperformed traditionally used trauma scoring systems including RTS, ISS, and SI.~~ This study also indicates potential opportunities to better apply REMS to the trauma population. REMS components HR and RR were found to have no statistically significant ~~difference~~ contribution in mortality prediction, while age and GCS were ~~either~~ over- or under-weighted in the REMS calculation, respectively.

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Injury type is an important predictor of mortality in trauma patients, and it was not included in the REMS calculation. Each of these represents an opportunity for future study.

Key Messages

- REMS is a more rapid and less invasive form of APACHE II, utilizing age, blood pressure, HR, GCS, RR, and peripheral oxygen saturation
- REMS performed similarly to RTS in the trauma population but was ~~is~~ a better predictor of mortality ~~in the trauma population~~ than ~~RTS,~~ ISS or SI
- Age, MAP, oxygen saturation and GCS correlate with mortality, with GCS exhibiting the strongest correlation

List of Abbreviations

APACHE: Acute Physiology and Chronic Health Evaluation

AUC: Area under Receiver Operator Characteristic (ROC) Curve

CI: Confidence Interval

DBP: Diastolic Blood Pressure

ED: Emergency Department

EMS: Emergency Medical Service

GCS: Glasgow Coma Score

HR: Heart Rate

ISS: Injury Severity Score

MAP: Mean Arterial Pressure

OR: Odds Ratio

REMS: Rapid Emergency Medicine Score

ROC: Receiver Operator Characteristic

RR: Respiratory Rate

RTS: Revised Trauma Score

SBP: Systolic Blood Pressure

SI: Shock Index

Tables and Captions

Table 1 *REMS Scoring System*

	Score						
Variable	0	+1	+2	+3	+4	+5	+6
Age (years)	<45		45-54	55-64		65-74	>74
MAP	70-109		110-129 50-69	130-159	>159 ≤ 49		
HR (beats/min)	70-109		110-139 55-69	140-179 40-54	>179 ≤39		
RR (breaths/min)	12-24	25-34 10-11	6-9	35-49	>49 ≤ 5		
O_2 Saturation (%)	>89	86-89		75-85	<75		
GCS	14 or 15	11-13	8-10	5-7	3 or 4		

~~**MAP, Mean Arterial Pressure; HR, Heart Rate/Pulse; RR, Respiratory Rate; GCS, Glasgow Coma Score**~~

Table 2 *Baseline Characteristics and Hospital Course for 3,680 Trauma Patients*

	Dead (N=191) Mean (SD)*	**Alive (N=3,489) Mean (SD)***	***p*-Value**
Age~~,~~ (years)	43.7 (21.0)	36.5 (17.0)	<0.0001
Male~~,~~ (%)	77.0	73.7	0.0472
Race~~,~~ (%)			0.0564
White	59.2	62.4	
Black	23.5	23.2	
Other	17.3	14.4	
Length of Stay (days)	4.4 (8.0)	7.6 (15.2)	0. 0043
Systolic BP (mmHg)	104.1 (68.3)	142.5 (24.9)	<0.0001
Diastolic BP (mmHg)	61.1 (43.6)	84.6 (20.5)	<0.0001
HR (beats/min)	76.0 (49.7)	95.7 (20.7)	<0.0001
RR (breaths/min)	8.0 (11.0)	18.0 (6.8)	<0.0001
O_2 Saturation (%)	86.1 (30.2)	98.1 (3.8)	<0.0001
GCS	5.8 (4.6)	13.6 (3.4)	<0.0001

* Except where noted as %.

Table 3 *REMS Score Characteristics* (p < 0.0001) *3,680 Trauma Patients*

REMS	**Alive (N)**	**Dead (N)**	**Mortality ~~(%)~~**
0-2	1749	6	0.3%
3-5	999	20	2.0%

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6-9	547	39	6.7%
10-11	110	28	20.3%
12-13	53	26	32.9%
14-15	22	18	45.0%
16-19	8	33	80.5~~24.2~~%
20-21	1	13	92.9%
22-26	0	8	100.0%
Total	3489	191	5.2%

Table 4 ***Injury Scores for 3,680 Trauma Patients***

	N	Dead Mean (SD)	Alive Mean (SD)	*p*-Value
REMS Score	3,680	11.8 (5.4)	3.4 (3.2)	<0.0001
SI	3,633	0.79 (0.40)	0.69 (0.22)	<0.0001
RTS	3,680	3.5 (2.7)	7.4 (1.3)	<0.0001
ISS	3,671	30.0 (14.6)	11.3 (10.0)	<0.0001

Table 5 ***Multiple Logistic Regression for All Parameters in REMS***

Variable	OR	95% CI	*p*-Value
GCS	0.743	0.711, 0.777	<0.0001
O_2 Saturation (%)	0.961	0.940, 0.982	0.0004
Age (yrs)	1.034	1.024, 1.044	<0.0001
MAP	0.979	0.973, 0.986	<0.0001
HR (beats/min)	0.996	0.990, 1.002	0.2179
RR (breaths/min)	1.001	0.978, 1.025	0.9023

Table 6 ***Blunt vs. Penetrating Mortality 3,680 Trauma Patients***

REMS	Blunt Mortality ~~(%)~~	Penetrating Mortality ~~(%)~~	*p*-Value	Overall Mortality ~~(%)~~
0-2	0.3%	0.5%	0.6375	0.3%
3-5	1.7%	3.0%	0.2542	2.0%
6-9	5.6%	14.9%	0.0082	6.7%
10-11	15.5%	45.4%	0.0031	20.3%
12-13	29.7%	46.7%	0.2329	32.9%
14-15	41.7%	75.0%	0.3100	45.0%
16-19	75.0%	92.3%	0.3983	80.5~~24.2~~%
20-21	85.7%	100.0%	1.0000	92.9%
22-26	100.0%	100.0%		100.0%

Total	4.4%	8.0%	<0.0001	5.2%

Competing Interests

The author(s) declare that they have no competing interests.

Authors' Contributions

BI participated in designing and coordinating the execution of the study, conducted the chart review, and drafting the manuscript. NT participated in designing and coordinating the execution of the study, and drafting the manuscript. MH participated in coordinating the execution of the study. NN performed the statistical analysis. MM participated in the design of the study and drafting the manuscript. CC participated in the design of the study and drafting the manuscript. All authors read and approved the manuscript.

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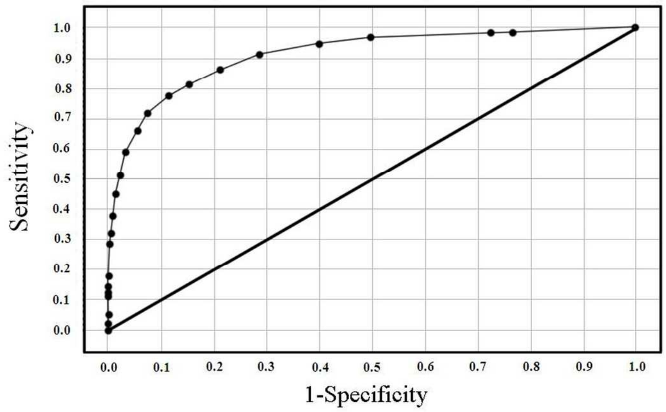
Figure 1. REMS ROC Curve
(Area Under Curve = 0.91)



Scoring System	Area Under Curve
REMS	0.91
RTS	0.89
ISS	0.87
SI	0.55

161x90mm (300 x 300 DPI)